GENERAL CHEMISTRY

CHAPTER 1

Chemistry: The Study of Change

☕ ONE-DAY CRASH COURSE

Learn → Practice → Answers → Next Topic
No giant wall of information.

🎯 THE GOAL

Understand the concepts AND be able to solve the problems independently.

Science, Chemistry, Technology & Alchemy

SCIENCE

A systematic way of gaining knowledge by observing, testing, and using evidence.

CHEMISTRY

The study of matter, its properties, composition, and the changes it undergoes.

TECHNOLOGY

The application of scientific knowledge to solve practical problems.

ALCHEMY

An early tradition involving matter, transformation, and attempts to understand

GREEN CHEMISTRY

Designing chemical products and processes to reduce or eliminate hazardous substances and waste at the source.

SUSTAINABLE CHEMISTRY

Chemistry designed with long-term environmental, economic, and social sustainability in mind.

MEMORY TRICK • Science discovers → Technology applies

Green Chemistry = Prevent the Problem

BIG IDEA

Traditional pollution control often asks:
“How do we clean up the waste?”

Green chemistry asks:
“How do we avoid creating

REDUCES RISK

Use safer chemicals, safer reaction conditions, renewable materials, and processes that create fewer hazards.

PREVENTS DAMAGE

Less hazardous waste → less pollution → lower exposure → fewer environmental problems.

EXAMPLE

Replacing a hazardous solvent with a safer alternative.

EXAMPLE

Designing reactions that use more of the starting materials and produce less waste.

EXAMPLE

Using less energy or carrying out reactions under milder conditions.

⚠ **TEST TRAP: Green chemistry is NOT simply “cleaning up pollution.” It focuses on PREVENTION.**

Your Turn ?

QUESTION 1

1. Which statement best describes chemistry?
A. Study of living organisms
B. Study of matter and its changes
C. Design of computers
D. Study of planets

QUESTION 2

2. Which approach best represents green chemistry?
A. Clean pollution after it forms
B. Create more waste, then recycle it
C. Prevent hazardous waste at the source
D. Ignore environmental effects

QUESTION 3

3. Technology is best described as:
A. Application of scientific knowledge
B. A scientific law
C. A type of matter
D. An ancient form of alchemy

QUESTION 4

4. A company redesigns a reaction so it uses a safer solvent and produces less hazardous waste. Is this green chemistry? Why?

⃠ Don't peek. Answers are on the NEXT slide.

Check Yourself ✓

ANSWER 1

1. B — Chemistry studies matter, its properties, composition, and changes.

ANSWER 2

2. C — Green chemistry prevents or reduces hazardous substances and waste at the source.

ANSWER 3

3. A — Technology applies scientific knowledge to practical problems.

ANSWER 4

4. YES — Safer solvents + less hazardous waste = prevention at the source.

Scientific Reasoning

HYPOTHESIS

A testable explanation or prediction based on observations.

LAW

Describes a consistent pattern or relationship in nature.

WHAT happens.

THEORY

A well-supported explanation of how or why natural phenomena occur.

MODEL

A representation used to visualize, explain, or predict a system.

VERY IMPORTANT

A scientific theory does NOT “become” a scientific law. Laws and theories serve different purposes: law = WHAT happens; theory = HOW/WHY it happens.

5-SECOND RULE: HYPOTHESIS = testable idea • LAW = what • THEORY = how/why • MODEL = representation

Evidence Changes Scientific Knowledge

OBSERVE

Scientists notice patterns or unexpected results.

TEST

Evidence is gathered through observations and experiments.

REVISE

Strong new evidence can strengthen, modify, or challenge scientific explanations.

TEST TRAP

Science is NOT about proving an idea forever. Scientific knowledge is evidence-based and can be revised.

KNOW THIS

A model can change when new evidence shows that the model does not adequately explain observations.

Your Turn ?

QUESTION 1

1. “Objects accelerate toward Earth at a predictable rate.” This is most like a:
A. Hypothesis
B. Law
C. Model
D. Opinion

QUESTION 2

2. Which best describes a scientific theory?
A. A random guess
B. A well-supported explanation
C. A single observation
D. A mathematical unit

QUESTION 3

3. TRUE or FALSE:
A scientific theory eventually becomes a scientific law.

QUESTION 4

4. A scientist creates a 3D representation of a molecule to visualize its structure. This is a:
A. Law
B. Theory
C. Model
D. Hypothesis

Check Yourself ✓

ANSWER 1

1. B — A law describes a consistent pattern: WHAT happens.

ANSWER 2

2. B — A theory is a well-supported explanation of HOW or WHY something happens.

ANSWER 3

3. FALSE — Theories and laws are different types of scientific knowledge.

ANSWER 4

4. C — A model is a representation used to visualize or explain something.

Risk & Benefit

⚠ RISK

The possibility that an activity, substance, or decision could cause harm.

✨ BENEFIT

A positive outcome or advantage produced by an activity, substance, or decision.

⚖ RISK–BENEFIT ANALYSIS

Ask BOTH questions:
What could we gain?
What could go wrong?

Then compare the magnitude of the benefit with the magnitude of the risk.

🧠 **Think: “Is the payoff worth the risk?”**

📊 DESIRABILITY QUOTIENT

A simple way to compare benefit and risk:

DQ = Benefit ÷ Risk

Higher DQ → generally more desirable.

Desirability Quotient — Worked Example

EXAMPLE

Suppose a decision has:

Benefit = 80
Risk = 20

DQ = Benefit ÷ Risk

DQ = 80 ÷ 20

DQ = 4

A DQ of 4 means the benefit is four times the numerical risk value.

HOW TO THINK

1. Identify benefit.
2. Identify risk.
3. Divide benefit by risk.
4. Compare the result.

⚠ Remember: A numerical DQ is a decision aid. Real-world risk assessment can involve much more than one simple ratio.

Your Turn ?

QUESTION 1

1. A chemical process has benefit = 90 and risk = 30. What is the DQ?

QUESTION 2

2. Which statement describes risk?
A. Positive outcome
B. Possibility of harm
C. Guaranteed benefit
D. Scientific theory

QUESTION 3

3. If Benefit = 60 and Risk = 10, what is the DQ?

QUESTION 4

4. Why should a decision-maker consider BOTH risk and benefit?

Check Yourself ✓

ANSWER 1

1. DQ = 90 ÷ 30 = 3.

ANSWER 2

2. B — Risk is the possibility that harm could occur.

ANSWER 3

3. DQ = 60 ÷ 10 = 6.

ANSWER 4

4. Because focusing only on benefits can ignore possible harm, while focusing only on risk can ignore useful outcomes.

Scientific Research

🔎 BASIC RESEARCH

Goal: increase knowledge and understanding.

It may not have an immediate practical application.

Example:
Studying how a newly discovered molecule behaves under different conditions.

🛠 APPLIED RESEARCH

Goal: solve a specific practical problem or develop a useful application.

Example:
Developing a new material designed to make batteries last longer.

🧠 MEMORY TRICK: BASIC = understand • APPLIED = solve

Basic or Applied? 🤔

QUESTION 1

1. Scientists investigate how a newly discovered protein folds, without a specific product in mind.

QUESTION 2

2. Researchers develop a water filter designed to remove a specific contaminant.

QUESTION 3

3. Scientists investigate the properties of an unknown material simply to understand it better.

QUESTION 4

4. A research team designs a cheaper solar-cell material for commercial use.

Check Yourself ✓

ANSWER 1

1. BASIC — The main goal is understanding.

ANSWER 2

2. APPLIED — It targets a specific practical problem.

ANSWER 3

3. BASIC — The goal is knowledge rather than an immediate application.

ANSWER 4

4. APPLIED — The research is aimed at creating a useful technology.

Matter, Mass & Weight

MATTER

Anything that has mass and occupies space.

MASS

The amount of matter in an object.

Usually measured in grams (g) or kilograms (kg).

Mass does NOT depend on location.

WEIGHT

A force caused by gravity acting on mass.

Weight changes when gravity changes.

Measured in force units such as newtons (N).

⚠ TEST TRAP: Your mass stays the same on the Moon; your weight changes.

Physical vs. Chemical

PHYSICAL CHANGE

Changes the form, state, size, or appearance of a substance WITHOUT creating a new substance.

Examples: melting ice, cutting paper, dissolving sugar.

CHEMICAL CHANGE

Produces one or more NEW substances with different compositions/properties.

Examples: rusting iron, burning wood, reacting acid + base.

THE GOLDEN QUESTION

“Did a NEW substance form?”

YES → chemical change
NO → physical change

WATCH OUT

A change in appearance alone does NOT automatically mean chemical change. Focus on whether the substance's composition changed.

Physical vs. Chemical Properties

👀 PHYSICAL PROPERTY

Can be observed or measured WITHOUT changing the substance's identity.

Examples:
- density
- color
- melting point
- boiling point

□ CHEMICAL PROPERTY

Describes how a substance can undergo a chemical change.

Examples:
- flammability
- ability to rust
- reactivity with acid
- tendency to decompose

🧠 MEMORY TRICK

PROPERTY = what it IS capable of doing. CHANGE = what actually HAPPENS.

Your Turn ?

QUESTION 1

1. Ice melting is a:
A. Chemical change
B. Physical change

QUESTION 2

2. Iron rusting is a:
A. Chemical change
B. Physical change

QUESTION 3

3. Flammability is a:
A. Physical property
B. Chemical property

QUESTION 4

4. Density is a:
A. Physical property
B. Chemical property

QUESTION 5

5. A substance reacts with acid and forms new substances. What kind of change occurred?

Check Yourself ✓

ANSWER 1

1. B — Melting changes the state but does not create a new substance.

ANSWER 2

2. A — Rusting creates iron oxide, a new substance.

ANSWER 3

3. B — Flammability describes how a substance reacts during burning.

ANSWER 4

4. A — Density can be measured without changing the substance.

ANSWER 5

5. Chemical change — New substances formed.

Classification of Matter

MATTER

Everything that has mass and occupies space.

```
MATTER
├── PURE SUBSTANCE
│   ├── ELEMENT
│   └── COMPOUND
└── MIXTURE
    ├── HOMOGENEOUS
    └── HETEROGENEOUS
```

PURE SUBSTANCE

Fixed composition.

ELEMENT → one type of atom
COMPOUND → elements chemically bonded

MIXTURE

Substances physically combined.

HOMOGENEOUS → uniform throughout
HETEROGENEOUS → nonuniform

States of Matter

SOLID

- Definite shape
- Definite volume
- Particles closely packed
- Particles vibrate in place

LIQUID

- No definite shape
- Definite volume
- Particles close together
- Particles flow past one another

GAS

- No definite shape
- No definite volume
- Particles far apart
- Particles move freely

Classify It ⁉

QUESTION 1

1. Oxygen gas (O_2) is:
A. Element
B. Compound
C. Homogeneous mixture

QUESTION 2

2. Water (H_2O) is:
A. Element
B. Compound
C. Mixture

QUESTION 3

3. Salt water is usually:
A. Element
B. Compound
C. Homogeneous mixture

QUESTION 4

4. A bowl containing oil and water is:
A. Homogeneous
B. Heterogeneous

QUESTION 5

5. Which has a definite volume but no definite shape?
A. Solid
B. Liquid
C. Gas

Check Yourself ✓

ANSWER 1

1. A — O_2 contains only one type of atom: oxygen.

ANSWER 2

2. B — H_2O contains hydrogen and oxygen chemically bonded.

ANSWER 3

3. C — Salt water is uniform throughout at the macroscopic level.

ANSWER 4

4. B — Oil and water form visibly different regions.

ANSWER 5

5. B — Liquids have definite volume but take the shape of their container.

Measurement & Units

LENGTH

Common unit:
meter (m)

Examples:
cm, mm, km

MASS

Common units:
gram (g)
kilogram (kg)

Chemistry often uses grams.

VOLUME

Common units:
liter (L)
milliliter (mL)
cm^3

TEMPERATURE

Common scales: °C, °F, K

MEASUREMENT

A measurement includes a NUMBER + UNIT.

Dimensional Analysis

THE RULE

PUT THE UNIT YOU WANT ON TOP.
PUT THE UNIT YOU HAVE ON THE BOTTOM.

Example:

2500 mL × (1 L / 1000 mL)

mL cancels → L remains

= 2.5 L

UNIT CANCELLATION

Units behave like algebra.

If the same unit appears on top and bottom, it cancels.

The final unit should be the unit you were asked to find.

⚠ **TEST TRAP: If the units do NOT cancel correctly, your conversion factor is probably upside down.**

Convert It

QUESTION 1

1. Convert 3.5 L to mL.

QUESTION 2

2. Convert 750 mL to L.

QUESTION 3

3. Convert 2.4 kg to g.

QUESTION 4

4. Convert 8500 mg to g.

QUESTION 5

5. What should happen to the unwanted unit during dimensional analysis?

Step-by-Step ✓

ANSWER 1

1. 3.5 L × (1000 mL / 1 L) = 3500 mL.

ANSWER 2

2. 750 mL × (1 L / 1000 mL) = 0.750 L.

ANSWER 3

3. 2.4 kg × (1000 g / 1 kg) = 2400 g.

ANSWER 4

4. 8500 mg × (1 g / 1000 mg) = 8.5 g.

ANSWER 5

5. It should cancel. The desired unit should remain.

Density

WHAT IS DENSITY?

Density tells you how much mass is packed into a certain volume.

Think:
“How crowded is the matter?”

Formula:

$\rho = m / V$

ρ = density
m = mass
V = volume

THE FORMULA TRIANGLE

$$\frac{m}{\rho \times V}$$

$\rho = m / V$

$m = \rho V$

$V = m / \rho$

COMMON UNITS

Density:
g/mL
g/cm^3
kg/m^3

Remember:
1 mL = 1 cm^3

So g/mL and g/cm^3 are numerically equivalent for the same density.

MEMORY TRICK: Density = MASS packed into each unit of VOLUME.

Density — Worked Example

EXAMPLE

A sample has a mass of 50 g and a volume of 10 mL.

$\rho = m / V$

$\rho = 50\ g / 10\ mL$

$\rho = 5\ g/mL$

☑ Answer: 5 g/mL

SOLVING ANY DENSITY PROBLEM

1. Write the formula.
2. Identify what you know.
3. Substitute values + units.
4. Calculate.
5. Check the final unit.

⚠ Units are part of the answer.

Density Problems ❓

QUESTION 1

1. A sample has m = 40 g and V = 8 mL. Find density.

QUESTION 2

2. A liquid has density = 2 g/mL and volume = 15 mL. Find mass.

QUESTION 3

3. A metal has mass = 60 g and density = 3 g/cm³. Find volume.

QUESTION 4

4. Which equation finds volume?
A. V = ρ/m
B. V = m/ρ
C. V = mρ

QUESTION 5

5. Why is g/mL a useful density unit?

Step-by-Step ✓

ANSWER 1

1. ρ = m/V = 40 g ÷ 8 mL = 5 g/mL.

ANSWER 2

2. m = ρV = (2 g/mL)(15 mL) = 30 g.

ANSWER 3

3. V = m/ρ = 60 g ÷ 3 g/cm³ = 20 cm³.

ANSWER 4

4. B — V = m/ρ.

ANSWER 5

5. It directly relates mass in grams to volume in milliliters.

Heat vs. Temperature

HEAT

Energy transferred between objects because of a temperature difference.

Heat flows from warmer objects toward cooler objects.

Think: ENERGY TRANSFER.

TEMPERATURE

A measure related to the average kinetic energy of particles.

Higher temperature → greater average particle motion.

⚠ TEST TRAP

Temperature is NOT the same thing as total thermal energy. A large object and small object can have the same temperature but different amounts of thermal energy.

Temperature Scales

US FAHRENHEIT

Water freezes:
32 °F

Water boils:
212 °F

Common in the United States.

CELSIUS

Water freezes:
0 °C

Water boils:
100 °C

Common in science and around the world.

KELVIN

Water freezes:
273.15 K

Water boils:
373.15 K

⚠ Kelvin is written K — NOT °K.

Temperature Conversion Formulas

°F → °C

$$°C = (5/9)(°F - 32)$$

°C → °F

$$°F = (9/5)°C + 32$$

°C → K

$$K = °C + 273.15$$

EXAMPLE

25 °C → K

K = 25 + 273.15 = 298.15 K

Notice: NO degree symbol with Kelvin.

Temperature Problems ❓

QUESTION 1

1. Convert 25 °C to K.

QUESTION 2

2. Convert 68 °F to °C.

QUESTION 3

3. Convert 100 °C to °F.

QUESTION 4

4. TRUE or FALSE: Kelvin is written °K.

QUESTION 5

5. Which describes temperature?
A. Energy transferred because of a temperature difference
B. A measure related to average particle kinetic energy

Step-by-Step ✓

ANSWER 1

1. K = 25 + 273.15 = 298.15 K.

ANSWER 2

2. °C = (5/9)(68 − 32) = (5/9)(36) = 20 °C.

ANSWER 3

3. °F = (9/5)(100) + 32 = 212 °F.

ANSWER 4

4. FALSE — Kelvin is written K, not °K.

ANSWER 5

5. B — Temperature relates to the average kinetic energy of particles.

Critical Thinking

EVIDENCE

What data actually support the claim?

Not all evidence is equally strong.

SOURCES

Ask:
Who produced this?
What evidence is provided?
Is the source reliable?

CORRELATION

Two things change together.

⚠ Correlation does NOT automatically mean one caused the other.

ASSUMPTIONS

What is being assumed but not actually demonstrated?

ALTERNATIVES

Could another explanation account for the evidence?

DATA

Look for misleading scales, cherry-picked data, missing context, or distorted graphs.

How to Evaluate a Claim

1 CLAIM

What exactly is being claimed?

Be specific.

2 EVIDENCE

What data support it?

Is the evidence relevant?

3 SOURCE

Who produced the evidence?

Can the source be trusted?

4 ALTERNATIVE

Could something else explain the result?

Correlation ≠ causation.

BEST QUESTION TO ASK: “Does the evidence actually support the claim?”

Think Like a Scientist

QUESTION 1

1. A graph uses a y-axis that starts at 98 instead of 0, making a small difference look huge. What should you do?

QUESTION 2

2. A study finds that people who carry umbrellas are more likely to get wet. Does carrying umbrellas cause people to get wet?

QUESTION 3

3. An influencer says “this chemical is completely safe” but provides no data. Is the claim adequately supported?

QUESTION 4

4. Why should scientists consider alternative explanations?

Think Like a Scientist ✓

ANSWER 1

1. Be cautious. A truncated axis can exaggerate visual differences.

ANSWER 2

2. No. Wet weather may cause BOTH umbrella use and getting wet. Correlation does not prove causation.

ANSWER 3

3. No. A strong claim needs reliable evidence; simply saying something is safe is not enough.

ANSWER 4

4. Another explanation may account for the evidence. Considering alternatives reduces faulty conclusions.

Chapter 1 in 60 Seconds

SCIENCE

Science = evidence-based knowledge.

Chemistry = matter + properties + changes.

Technology = application.

Green chemistry = prevent hazards/waste at the source.

REASONING

Hypothesis = testable idea.

Law = WHAT happens.

Theory = HOW/WHY.

Model = representation.

Theory ≠ law.

MATTER

Physical change = no new substance.

Chemical change = new substance.

Element = one atom type.

Compound = bonded elements.

Mixture = physically combined.

Vocabulary Cheat Sheet

KNOW THIS

Matter — has mass and occupies space

KNOW THIS

Mass — amount of matter

KNOW THIS

Weight — gravitational force on mass

KNOW THIS

Physical property — observed without changing identity

KNOW THIS

Chemical property — describes chemical reactivity

KNOW THIS

Physical change — no new substance

KNOW THIS

Chemical change — new substance forms

KNOW THIS

Element — one type of atom

KNOW THIS

Compound — elements chemically bonded

KNOW THIS

Mixture — substances physically combined

KNOW THIS

Homogeneous — uniform

KNOW THIS

Heterogeneous — nonuniform

KNOW THIS

Density — mass per volume

KNOW THIS

Heat — energy transferred due to temperature difference

KNOW THIS

Temperature — related to average particle kinetic energy

Things Professors LOVE to Test ⚠

⚠ TEST TRAP
Evidence must actually support the claim.

⚠ TEST TRAP
Mass ≠ weight.

⚠ TEST TRAP
Correlation ≠ causation.

⚠ TEST TRAP
Chemical change → NEW substance.

⚠ TEST TRAP
Units must cancel in dimensional analysis.

⚠ TEST TRAP
Mixture ≠ compound.

⚠ TEST TRAP
Homogeneous = uniform throughout.

⚠ TEST TRAP
Physical property ≠ chemical property.

⚠ TEST TRAP
Element = one type of atom.

⚠ TEST TRAP
Heat ≠ temperature.

⚠ TEST TRAP
Kelvin = K, NOT °K.

⚠ TEST TRAP
Theory does NOT become law.

⚠ TEST TRAP
Density = mass ÷ volume.

⚠ TEST TRAP
Green chemistry focuses on prevention.

Formula Sheet □

DENSITY

$$\rho = m / V$$

MASS

$$m = \rho V$$

VOLUME

$$V = m / \rho$$

FAHRENHEIT

$$°F = (9/5)°C + 32$$

CELSIUS

$$°C = (5/9)(°F - 32)$$

KELVIN

$$K = °C + 273.15$$

DESIRABILITY QUOTIENT

$$DQ = Benefit \div Risk$$

🎯 **ALWAYS INCLUDE UNITS IN YOUR CALCULATIONS.**

Chapter 1 Mixed Practice — Part 1

QUESTION 1

1. Which is a chemical change?
A. Melting ice
B. Cutting paper
C. Rusting iron

QUESTION 2

2. Which is a compound?
A. O_2
B. H_2O
C. Air

QUESTION 3

3. A density of 4 g/mL and volume of 10 mL gives what mass?

QUESTION 4

4. Which statement is correct?
A. Theory becomes law
B. Law explains why
C. Theory explains how/why

QUESTION 5

5. Convert 2.5 L to mL.

QUESTION 6

6. 25 °C is approximately:
A. 25 K
B. 248.15 K
C. 298.15 K
D. 325.15 K

Chapter 1 Mixed Practice — Part 2

QUESTION 7

7. Salt water is usually classified as a:
A. Element
B. Compound
C. Homogeneous mixture

QUESTION 8

8. A scientist studies a molecule's properties simply to increase knowledge. Basic or applied research?

QUESTION 9

9. Which is a chemical property?
A. Density
B. Melting point
C. Flammability

QUESTION 10

10. A claim says “Product X causes better grades” because students using it had higher grades. What major issue should you question?

QUESTION 11

11. Benefit = 75 and Risk = 15. Calculate DQ.

QUESTION 12

12. Which statement about mass and weight is correct?

Check Your Work ✓

1. C — Rusting forms new iron-containing substances. 1

2. B — H_2O contains two elements chemically bonded. 2

3. $m = \rho V = (4\ g/mL)(10\ mL) = 40\ g$. 3

4. C — Theory explains how/why; it does not become a law. 4

5. $2.5\ L \times 1000\ mL/L = 2500\ mL$. 5

6. C — $K = 25 + 273.15 = 298.15\ K$. 6

7. C — Salt water is uniform throughout. 7

8. BASIC — The goal is understanding rather than an immediate application. 8

9. C — Flammability describes chemical reactivity. 9

10. Correlation ≠ causation. Other explanations may exist. 10

11. $DQ = 75 \div 15 = 5$. 11

12. Mass is the amount of matter; weight is gravitational force on that mass. 12

OBJECTIVE CHECK

Did We Cover Everything? 🎯

- ✓ 1.1 — Science, chemistry, technology, alchemy, green & sustainable chemistry
- ✓ 1.2 — Hypothesis, law, theory, model + evidence relationships
- ✓ 1.3 — Risk, benefit, risk-benefit analysis & desirability quotient
- ✓ 1.4 — Basic vs. applied research
- ✓ 1.5 — Matter, mass vs. weight, physical/chemical properties & changes
- ✓ 1.6 — States of matter + element/compound/mixture classification
- ✓ 1.7 — Units, measurements, conversions & dimensional analysis
- ✓ 1.8 — Density, mass & volume calculations
- ✓ 1.9 — Heat, temperature, Celsius/Fahrenheit/Kelvin + conversions
- ✓ 1.10 — Critical thinking, evidence, sources, correlation/causation & data
- ✓ Additional — Green chemistry reduces risk and prevents environmental problems

YOU'VE GOT THIS.

Don't memorize everything at once.
Understand → practice → correct → repeat.